STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

REPORT OF INVESTIGATIONS—NO. 23

HIGH-CALCIUM LIMESTONE NEAR MORRIS, ILLINOIS

BY

J. E. LAMAR AND H. B. WILLMAN

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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SYNOPSIS

Two deposits of high-calcium limestone occur in Grundy County, Illinois, located less than 60 miles by rail from Chicago and immediately adjacent to the Elgin, Joliet and Eastern Railroad and the Illinois Waterway (fig. 1). Their favorable location with reference to transportation and their proximity to Chicago, which has but few nearby commercial sources of high-calcium limestone, make them of especial interest to producers and consumers of this type of limestone.

The larger or south tract lies south of the Illinois River and comprises an area of about 1700 acres in which the stone has a known maximum thickness of 44 feet, an estimated average thickness of about 21 feet, and overburden averaging less than 10 feet thick. It is estimated that this tract contains 133,000,000 tons of stone, of which 91,000,000 probably have less than 3½ feet of overburden. Because this tract adjoins the Dresden Island Lock and Dam of the Illinois Waterway it may be that only the southern half or two-thirds of its area will be available for quarrying involving heavy blasting. It is understood that the dam is intended to raise the level of the water to an elevation of 505 feet at the dam. This level is believed to be somewhat higher than the limestone area in parts of secs. 26, 25, and 36.

The smaller or northern tract lies north of Illinois River and contains limestone from a few to 36 feet thick. At some places the stone crops out; at others it is covered by overburden as much as 15 feet thick. This tract is estimated to comprise about 280 acres of stone having an average thickness of about 21 feet with an average overburden less than ten feet thick, and to contain approximately 21,000,000 tons of limestone, of which 14,000,000 tons probably have an overburden less than 3½ feet thick.

Additional stone may possibly be obtained by sub-surface mining under the uplands to the northeast of both the north and south tracts. (See topographic and geologic map, fig. 4.)

The analysis of a sample of slightly weathered stone shows that it contains more than 95 per cent calcium carbonate, and the unweathered stone doubtless contains an even higher percentage of calcium carbonate. The

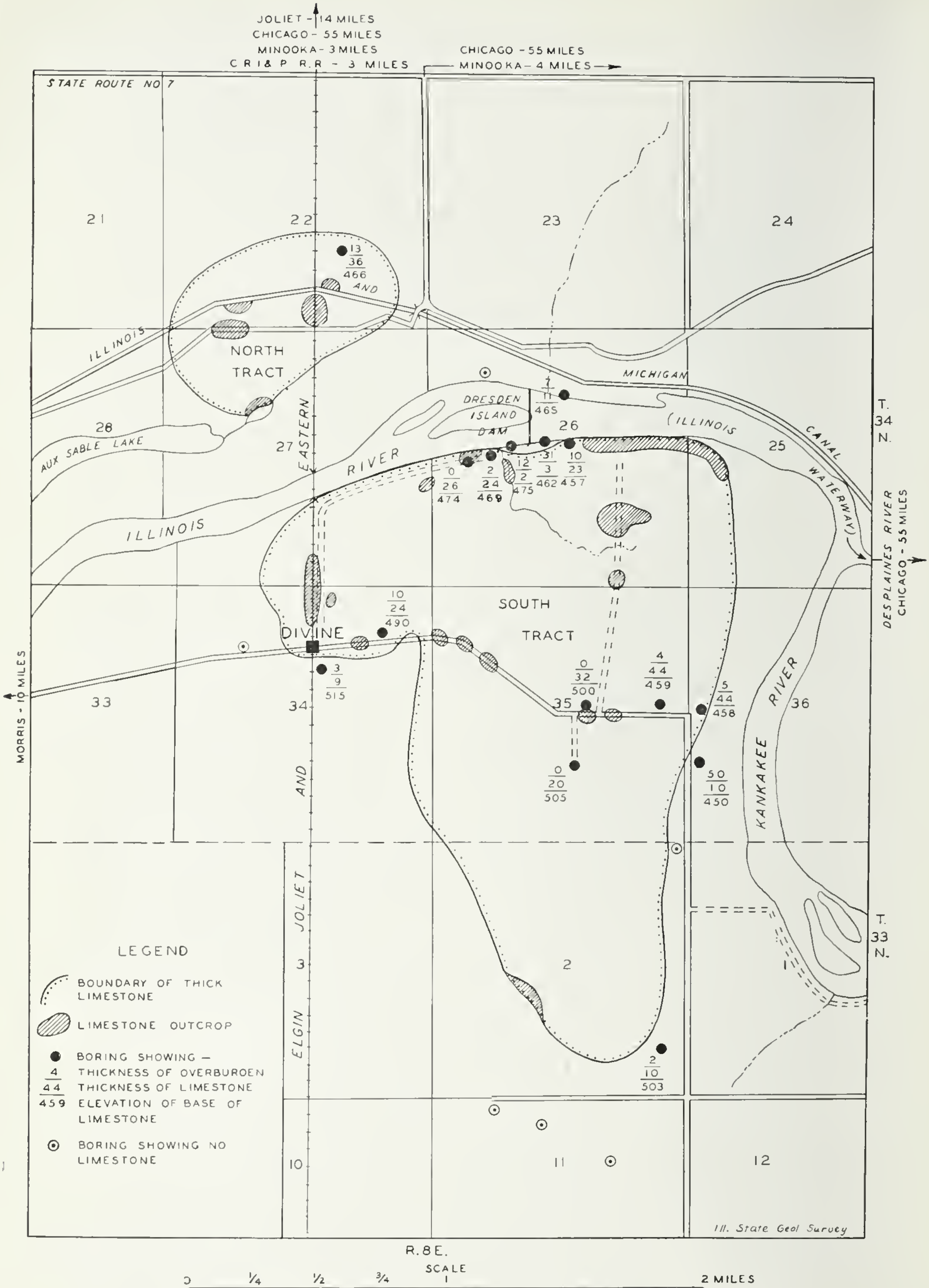

FIG. 1. Map of Divine area showing various pertinent geographic features, the position and probable extent of the two tracts of high-calcium limestone, the location of limestone outcrops and of borings, and skeletal records of borings. The area included in the two tracts is thought to be underlain by limestone averaging at least 21 feet thick and having an overburden averaging less than 10 feet thick (Table 4).

deposit as a whole is probably a uniformly high-calcium stone suitable for flux, lime, and agricultural limestone. Some of it may be white enough for whiting, and some of it may be used as commercial marble, as the stone polishes well and occurs in shades of gray, buff, pink, and perhaps white. According to available analyses the rock is low in magnesium carbonate, is located not far from clay deposits that are also low in magnesium carbonate, and may overlie a non-magnesian shale, all of which conditions appear favorable for cement manufacture. The stone is somewhat soft and probably cannot be recommended for use as concrete aggregate for road construction, or as railroad ballast.

The top and bottom surfaces of the limestone are uneven. Locally erosion channels may cut well into or even through the stone, thereby developing depressions in the upper surface or isolating certain portions of the limestone. Thorough test drilling of the deposit before commercial exploitation is begun is recommended.

INTRODUCTION

The constructional and industrial needs of metropolitan Chicago have created a tremendous demand for both magnesian limestone, commonly called dolomite, and limestone composed almost exclusively of calcium carbonate known as high-calcium or calcitic limestone. The Chicago district, however, lies in a portion of Illinois that is underlain almost exclusively by dolomite and although this stone admirably serves many purposes there are others, such as cement, and high-calcium lime and flux, for which high-calcium limestone is desired.

In view of this situation, unusual economic importance may be attached to the occurrence of a deposit of high-calcium limestone in eastern Grundy County, a few miles east of Morris, Illinois (fig. 1), located less than 60 miles from Chicago either by rail or water and lying along the Elgin, Joliet, and Eastern Railroad and the Illinois Waterway.

This deposit has been described in a general way in previous reports.[2] The present study brings together the earlier data and newer information obtained from a recent study of the deposit made in connection with a general investigation of the mineral resources along the Illinois Waterway.

Quarrying of this deposit may involve costs somewhat above the average because the limestone is not as thick or as regular as is considered ideal. However it seems likely that any additional costs on this account will be offset, largely, so far as competitive sales in the Chicago market are concerned, by the short haul and potential low cost of transportation to that market.

[2] Krey, Frank, and Lamar, J. E., Limestone resources of Illinois: Illinois State Geol. Survey Bull. 46, pp. 115-116, 1925.
Culver, H. E., Geology and mineral resources of the Morris quadrangle: Illinois State Geol. Survey Bull. 43-B, pp. 33-35, 1922.

ACKNOWLEDGMENTS

The writers are indebted to the Waterway Division of the Department of Purchases and Construction of the State of Illinois, who kindly permitted the use of data obtained from borings made in connection with the construction of the Dresden Island Lock, and to Mr. T. F. Anderson, well driller of Morris, Illinois, who furnished many records of wells drilled in the region covered by this study. Considerable data were obtained from Bulletin 43-B of the Illinois State Geological Survey, "The Geology and Mineral Resources of the Morris Quadrangle," by H. E. Culver, published in 1919.

DETAILED DESCRIPTION

Geologic Features

The limestone is a part of the Cincinnatian series (Richmond formation) in the Ordovician system and is herein named the "Divine limestone" because it occurs in the vicinity of Divine station on the Elgin, Joliet, and Eastern Railroad. The Richmond formation consists largely of shale but locally contains strata of high-calcium limestone, dolomite, and shaly limestone. The maximum recorded thickness of any bed of Richmond limestone in northeastern Illinois is about 80 feet,[3] but the Divine limestone comprises the thickest high-calcium bed known within the Richmond formation, attaining a known maximum thickness of 44 feet (fig. 1, boring in SW. corner of the NW. ¼ sec. 36, T. 34 N., R. 8 E.). The formation dips or lowers to the northeast and has a northwest-southeast strike, as is roughly indicated by the western edge of the area of outcrop of relatively thick stone (fig. 4, p. 16). The base of the limestone is shown to be uneven by the variations in its elevation which are departures from the normal northeast dip of the formation (fig. 1).

The Divine limestone is underlain by Richmond shale, normally 50 to 70 feet thick although as little as 15 feet of shale is reported to occur at some places. The limestone is overlain by recent or Pleistocene alluvium or by shale or clay, usually of Richmond age but locally of early Pennsylvanian (Coal Measures) age. The overlying shales are relatively thin near the outcrop of the limestone, but thicken to more than 50 feet some distance away.

Lithologic Character

The exposed limestone is generally coarse-grained, crystalline, and usually white, light gray, or buff in color, although locally, as immediately north of Divine, it is pink or brown. Where fresh it is composed of strata from 8 to 14 inches thick which commonly weather to slabs from 2 to 4 inches thick

[3] Fisher, D. J., Geology and mineral resources of the Wilmington quadrangle, Illinois State Geol. Survey. Unpublished manuscript.

TABLE 1.—*General sequence of strata in vicinity of Divine*

	Thickness
Recent system	*Feet*
Silt, sand, gravel and peat	0-10
Pleistocene system	
Till, clay, silt, sand and gravel	0-60
Pennsylvanian system	
Carbondale and Pottsville formations	
Shale, clay, sandstone, and coal	0-50
Ordovician system	
Cincinnatian series	
Richmond formation	
Shale, dark gray	0-7
Limestone (Divine member), coarsely crystalline, fossiliferous	0-44
Shale, calcareous, gray, non-gritty	13-70
Mohawkian series	
Galena formation	
Dolomite, light gray, fine-grained	....

(fig. 2). Fossils, complete and fragmentary, are common and locally comprise a major part of the stone. Pyrite was observed but rarely, however it is reported that some of the Divine limestone removed from excavations for the foundations of the Dresden Island Dam contained a large amount of this mineral. No shale or clay strata more than a fraction of an inch in thick-

FIG. 2. Exposure of Divine limestone along Elgin, Joliet and Eastern Railroad about a quarter of a mile north of Divine. This outcrop is weathered as indicated by the manner in which the strata are split and broken.

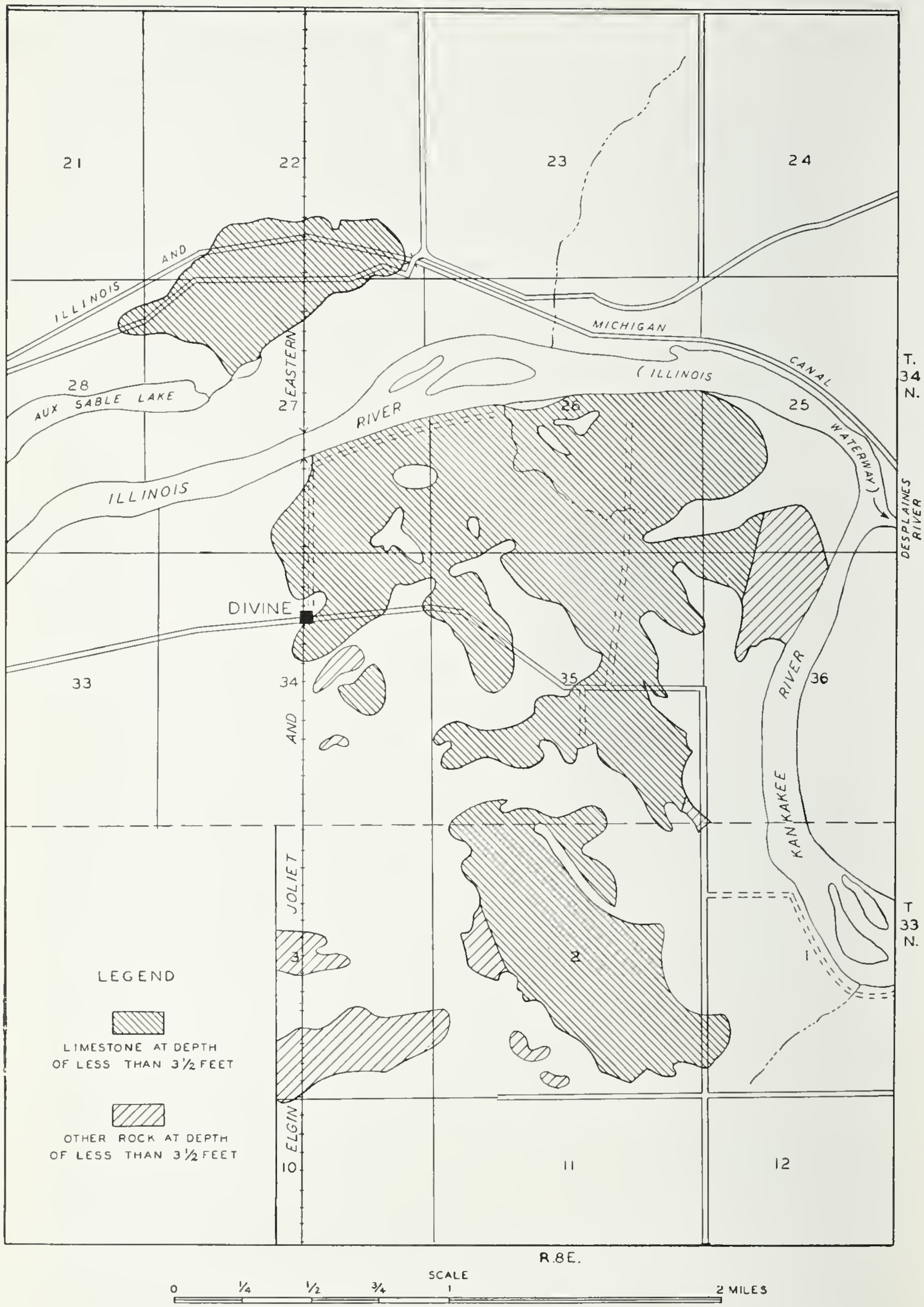

FIG. 3. Map of Divine region showing probable areas where limestone or other rock occurs at a depth of less than 3½ feet. The probable positions of glacial channels of unknown depths are suggested by the blank areas in the south tract. (Modified from the Grundy County Soil Map in "Grundy County Soils," by Smith, R. S., DeTurk, E. E., Bauer, F. E., and Smith, L. H., University of Illinois Agricultural Experiment Station, Soil Report No. 26, March, 1924.)

ness were noted, and it is thought that the member normally contains no interbedded shales. The entire formation is not exposed at any one place, but the lower part is exposed along the south bank of Illinois River near the center of sec. 26, T. 34 N., R. 8 E. The upper part is exposed along the road near the center of sec. 35 of the same township and also in the railroad cut and in the abandoned quarry immediately north of Divine.

Physical Character

The physical properties of the unweathered Divine limestone are not known in detail but tests made on a sample obtained from the least weathered outcrop available, namely that in the railroad cut about a quarter of a mile north of Divine, in the center of the north line of sec. 34, T. 34 N., R. 8 E. (fig. 1), gave the following results.

Table 2—*Physical analysis of Divine limestone*[a]

Specific gravity	2.68
Weight, pounds per cubic foot	167.
Water absorption, per cent	0.59
Water absorbed, pounds per cubic foot	0.79
French coefficient of wear	5.0
Hardness	8.7
Toughness	4.00
Cementing value	40.

The results of these tests show that, compared to other Illinois limestones and dolomites[4], the stone exposed in the railroad cut is of average specific gravity and weight per cubic foot, low water absorption, low-medium resistance to wear as measured by the French coefficient, low hardness and toughness, and medium cementing value. Tests on samples of unweathered limestone will probably show a somewhat higher French coefficient, hardness, and toughness, but the Divine stone generally will probably not have a high rating with respect to these coefficients.

Chemical Composition

Only one complete chemical analysis of the Divine limestone has been made. The sample tested was taken from the outcrops along the Elgin, Joliet and Eastern Railroad about a quarter of a mile north of Divine station, in the center of the north line of sec. 34, T. 34 N., R. 8 E., where about 4 feet of limestone is exposed (figs. 1 and 2). (See Table 3, p. 17.)

[a] Analysis by the Testing Laboratory of the Illinois State Division of Highways.
[4] Krey, Frank, and Lamar, J. E., The limestone resources of Illinois, Illinois State Geol. Survey, Bull. 46, pp. 39 and 47-63, 1925.

TABLE 5.—*Limestone sold or used by producers in Illinois,*

Limestone—	Illinois Quantity tons	Illinois Value dollars	Illinois Average price per ton	Michigan Quantity tons	Michigan Value dollars	Michigan Average price per ton
Flux	786,000	749,721	.95	7,365,300	4,599,477	.62
Sugar refineries	......	......	..	12,400	18,800	1.51
Glass factories	*b*	*b*	*b*	*b*	*b*	*b*
Paper mills	......	......	..	*b*	*b*	*b*
Agriculture	947,800	843,693	.89	182,660	187,500	1.03
Concrete and road metal	5,327,310	4,221,762	.79	2,218,550	1,372,500	.62
Railroad ballast	936,240	724,302	.77	239,910	158,554	.66
Alkalie works	*c*	*c*	*c*	*c*	*c*	*c*
Asphalt filler	*c*	*c*	*c*	*c*	*c*	*c*
Riprap	135,080	132,971	.98	*b*	*b*	*b*
Calcium carbide works	*c*	*c*	*c*	*c*	*c*	*c*
Rubble	*b*	*b*	*b*	......	......	......
Coal mine dusting	*c*	*c*	*c*	*c*	*c*	*c*
Mineral food	*c*	*c*	*c*	*c*	*c*	*c*
Poultry grit	*c*	*c*	*c*	*c*	*c*	*c*
Whiting substitute	*c*	*c*	*c*	*c*	*c*	*c*
Stucco, terrazzo, and artificial stone	*c*	*c*	*c*	*c*	*c*	*c*
Building						
Rough construction	3,310	3,408	..	......	......	......
Rough architectural	[e]9,000	15,000	..	......	......	......
Finished, sawed, and cut	......	......	..	......	......	......
Lime[d]	119,382	972,312	8.15	91,468	844,543	9.23
Other uses and those for which production is not listed above	199,540	257,364	1.29	3,430,700	1,921,103	.56

a Coons, A. T., Stone in 1929, Mineral Resources of the United States, 1929, Part II, pp. 251-254.
b Less than 3 producers. Statistics not available for publication.
c No data available.
d Indicates production of lime, not limestone.
e Quantity in cubic feet.

Michigan, Indiana, Wisconsin, and United States in 1929[a]

Indiana			Wisconsin		United States		
Quantity tons	Value dollars	Average price per ton	Quantity tons	Value dollars	Quantity tons	Value dollars	Average price per ton
132,060	27,397	.21	11,890	9,579	24,337,280	17,994,110	.74
......	......	....	......	......	487,990	874,909	1.79
b	*b*	*b*	......	......	257,370	455,367	1.76
......	......	....	......	......	273,880	456,251	1.66
154,590	176,514	1.14	67,510	122,882	2,654,580	3,764,775	1.42
3,033,890	2,748,016	.91	3,068,750	3,000,198	50,090,350	50,057,122	1.00
467,490	415,490	.89	62,980	51,003	11,374,850	8,877,328	.78
c	*c*	*c*	*c*	*c*	5,004,930	3,234,457	.67
c	*c*	*c*	*c*	*c*	344,880	1,165,538	3.37
109,660	34,422	.31	100,350	113,728	2,080,580	2,655,374	1.28
c	*c*	*c*	*c*	*c*	339,510	236,412	.70
b	*b*	*b*	29,790	101,356	354,480	693,678	1.96
c	*c*	*c*	*c*	*c*	34,650	121,712	3.51
c	*c*	*c*	*c*	*c*	25,270	96,009	3.80
c	*c*	*c*	*c*	*c*	34,600	221,610	6.40
c	*c*	*c*	*c*	*c*	125,430	626,692	5.00
c	*c*	*c*	*c*	*c*	85,540	292,313	3.42
......	......	....	10,370	44,860	178,490	280,564	....
[e]5,349,190	2,935,124	....	[e]144,490	141,907	6,192,550	3,779,639	....
[e]9,087,590	15,651,380	....	[e]19,320	86,937	[e]9,430,100	16,589,054	....
116,795	786,814	6.74	130,902	830,180	4,269,768	33,578,848	7.84
86,780	111,479	1.28	......	......	7,464,870	7,427,900	.99

Fig. 4. Topographic and areal geology map of Divine area showing probable extent of the thick and thin Divine limestone and over-and underlying formations. The glacial till locally contains sand and gravel. Topography copied from U. S. Geological Survey topographic map of Morris quadrangle; geology revised from geologic map in "Geology and Mineral Resources of the Morris Quadrangle," by H. E. Culver, Illinois State Geological Survey Bulletin 43-B, 1922.

Correction on map: the outcrop area shown southwest of the section number "26" should indicate thin Divine limestone (fig. 1, p. 8).

Table 3—*Analysis of limestone near Divine*[a]

Silica	0.94
Calcium oxide	53.73
(Calcium carbonate, 95.88)	
Magnesium oxide	0.91
(Magnesium carbonate 1.90)	
Iron oxide and alumina	1.14
Sulfuric anhydride	0.07
Ignition loss	43.57

Despite the fact that this sample came from a weathered outcrop and contained fragments of stone stained by iron oxide, the carbonates total 97.78 per cent and the impurities only 2.15 per cent. Other samples from outcrops near Divine contained 2 per cent or less of residues insoluble in hydrochloric acid. A sample of Divine limestone from a section of diamond drill core[5] obtained years ago while test drilling in the south half of sec. 2, T. 33 N., R. 8 E. contained only slightly more than 1 per cent of insoluble residue. All data at hand suggest that these tests are probably representative of the formation as a whole.

Thickness

The Divine limestone ranges in thickness from a few to 44 feet, owing to the fact that both its upper and lower surfaces are irregular. The average thickness is thought to be about 20-25 feet and is probably somewhat greater in the south than in the north tract. Owing to its dip the stone should thicken toward the northeast, although local erosion may cause exceptions to this tendency.

Overburden

Over a relatively large portion of the area indicated as probably underlain by workable stone (figs. 1, 3, and 4) the overburden is less than 3½ feet thick (fig. 3) ; its maximum thickness is possibly 20 feet, and the average thickness is about 10 feet. It appears to consist largely of unconsolidated clay, loam, sand, and gravel, which for the most part can probably be readily removed by hydraulic methods of stripping. However, a possible exception occurs in the north tract in the NW. ¼ SE. ¼ sec. 22, T. 34 N., R. 8 E., where a boring is reported to have penetrated 6½ feet of "soapstone" which may be Pennsylvanian shale or clay, although it is more probably glacial till.

a Analysis by the Testing Laboratory of the Illinois State Division of Highways.

[5] The exact depth at which the section of core was secured and the precise location of the boring are unknown.

FACTORS GOVERNING DISTRIBUTION OF LIMESTONE AND OVERBURDEN

The Divine region (fig. 4) is a part of a broad floodplain in a valley that was carved or eroded in bedrock by great floods which occupied Illinois, Kankakee, and DesPlaines river valleys during glacial times. In some places in this plain the erosion removed the bedrock that overlay the Divine limestone, in others it cut unevenly into the limestone or completely through the limestone leaving isolated remnants of irregular distribution. General sites of maximum flood erosion are indicated by the valleys or low swales in the region of relatively thick limestone, particularly in sec. 35, T. 34 N., R. 8 E. (figs. 3 and 4).

Similar effects resulted from another period of erosion many millions of years earlier, in the time preceding the deposition of the Pennsylvanian sediments. Although this earlier erosion did not greatly affect the limestone near Divine it did develop a locally uneven surface and resultant variations in thickness of the deposit, as well as some irregularities of distribution around the margins (fig. 3). Another consequence of the pre-Pennsylvanian erosion and subsequent deposition is the presence of Pennsylvanian strata at the same elevation as that of older beds, a situation which is well illustrated by the abrupt change from Divine limestone to Pennsylvanian strata along a line not far west of Kankakee River, across secs. 25, 36, and 35, T. 34 N., R. 8 E., and sec. 2, T. 33 N., R. 8 E.

Subsequent to the glacial erosion the limestone was covered by silt, sand, and gravel deposited by the glacial floods. This alluvium is as much as 21 feet thick but probably averages less than 10 feet (fig. 3) on the higher portion of the area underlain by limestone.

Quantity of Stone Available

The quantity of stone in the Divine area cannot be accurately calculated at present because the data available concerning the deposit are too meager and incomplete. However, a preliminary estimate of the area underlain by stone and the tonnage contained is here presented (Table 4). This estimate is based on an approximate average thickness of 21 feet of limestone and 3½ feet of overburden; a cubic yard of stone in place is calculated to weigh 2¼ tons. As it is possible that only certain portions of the Divine deposit will be quarried the estimate is presented by sections.

TABLE 4.—*Estimates of quantities of limestone present in the Divine area*

Section No.	Limestone more than 21 feet thick		Limestone more than 21 feet thick with less than 3½ feet of overburden, (included in preceding column)		Limestone of unspecified thickness with less than 3½ feet over-burden	Limestone with an average thickness of less than 21 feet, with less than 3½ feet over-burden
	Acres	*Tons*	*Acres*	*Tons*	*Acres*	*Acres*
			NORTH TRACT			
22	175	13,300,000	90	6,900,000	100	10
27	105	8,000,000	95	7,200,000	100	5
28						5
(Total)	280	21,300,000	185	14,100,000	200	20
			SOUTH TRACT			
25	60	4,600,000	50	3,800,000	60	10
26	365	27,800,000	340	25,900,000	340	0
27	165	12,600,000	130	9,900,000	130	0
34	130	9,900,000	70	5,300,000	95	25
35	635	48,400,000	345	26,300,000	345	0
36	50	3,800,000	15	1,100,000	15	0
1	0		0		10	10
2	340	25,900,000	250	19,000,000	295	45
(Total)	1,745	133,000,000	1,200	91,300,000	1,290	90

QUARRYING CONDITIONS

Owing to the fact that the Divine deposits lie along Kankakee and Illinois rivers, the possibility of seepage of river or other water into quarries in the limestone must be considered. However, water wells in the vicinity of Divine are ordinarily drilled to a horizon below the Divine limestone, and the limestone is reported to be dry. Inasmuch as the limestone dips to the east, natural drainage of ordinary rain and snow water away from the working face of a quarry could be obtained by beginning operations in the eastern part of the deposit and extending them westward.

It is understood that the Dresden Island dam and locks of the Illinois Waterway which have been built at the east end of Twin, or Dresden Island, in sec. 26, T. 34 N., 8 E. (fig. 1) will raise the water level of Illinois and Kankakee rivers to an elevation of 505 feet at the dam. This will not affect the north tract or that part of the south tract below the dam, but may flood a portion of the eastern part of the south tract, especially in secs. 26, 25,

and 36. The possibility of water seepage or overflow into a quarry will be materially increased but inasmuch as the velocity of Illinois and Kankakee rivers will be greatly reduced, probably causing slack-water conditions over most of secs. 25 and 36 and possibly sec. 26, the maintenance of levees to prevent flooding of the quarry would seem reasonably easy. Blasting in the general vicinity of the dam and locks will probably have to be restricted to light shots.

The Illinois and Michigan Canal which cuts across the north tract will probably not add seriously to the possibility of seepage, but the division of the deposit into two parts may be disadvantageous to economical quarrying. With the completion of the Illinois Waterway it is possible that the canal, which is little used, will be abandoned and in that case it would no longer constitute a possible obstacle to quarrying.

Recommendations for Exploration

It is recommended that exploration of both the north and south tracts include thorough core drilling and that the cores be carefully examined and tested to determine the chemical and physical properties of the stone. Results of these tests will form a basis for intelligent quarrying and utilization.

Other Areas Underlain by Limestone

The Dresden Heights bluffs along Illinois River in secs. 23, 24, and 26, T. 34 N., R. 8 E., are underlain by limestone, but as the bluffs are about 120 feet high (fig. 4) they definitely limit the eastern extent of open-pit quarrying. As far as is known they are composed of gravelly clay (glacial till) and unless part of the limestone is left as a roof, conditions for mining beneath the bluffs would probably be disadvantageous.

Limited outcrops of Richmond limestone occur at some places along Aux Sable Creek west of Minooka in secs. 3 and 4, T. 34 N., R. 8 E. and in secs. 34, 27, 22, and possibly others, in T. 35 N., R. 8 E. As far as is known the stone in these deposits is thinner, has a heavier overburden, and is less favorably situated with reference to transportation than that in the Divine region.

USES OF DIVINE LIMESTONE

The potential uses of the Divine limestone are numerous and include among others flux, lime, cement, agricultural limestone, poultry grit and mineral filler. Some of these uses, such as flux and lime, involve quantity production and comparatively little preparation of the stone, whereas others, such as agricultural limestone, poultry grit, etc., involve a smaller production but necessitate finer crushing or pulverizing. If test borings in the Divine

area indicate a large deposit of stone an operation combining the production of flux and/or lime with the manufacture of rock specialties such as poultry grit, agricultural limestone, mineral foods, stucco and terrazzo chips and the like may be the most profitable. If, however, the deposit is found unfavorable for large scale development the production of rock specialties may still be profitable. From the rather limited data available, the Divine limestone is thought to be suited to the uses enumerated below.

Flux

The high-calcium and probably low sulfur content of the Divine limestone makes it appear to be an excellent flux for smelting iron. The phosphorous content of the stone is not known but it is probably low, and in other respects the rock compares favorably with other stone now used for commercial fluxes. The stone is also probably suitable for flux in smelting siliceous copper ores and in the lime-roasting process of desulferizing lead ores. Table 5 shows that in 1929 flux stone in Illinois sold for an average of 95 cents per ton, whereas in Michigan it netted 62 cents per ton. Considerably more than half of Illinois' production of flux comes from quarries in the Niagaran dolomite in Cook county which ship to steel mills in the Chicago district. In Monroe and St. Clair counties in the southwestern part of the State are other important flux producing areas which ship principally to the St. Louis market.

Lime

The Divine limestone, with the exception of the iron-stained portions of the formation, seems well suited to the manufacture of high-calcium lime because of its purity and high-calcium carbonate content. The most important lime producing centers in Illinois are the Chicago and Quincy districts. The lime manufactured in the Chicago district from local stone is high-magnesium lime, but a large percentage of the State production is made from high-calcium limestone brought to Chicago by boat from the northern part of the Michigan peninsula. Production statistics for lime are shown in Table 5 (pp. 14-15).

Portland Cement

In Illinois, Portland cement is commonly made from a raw mix of clay and limestone in proportions of about 1 to 3. The purity of the Divine limestone makes it suitable for cement making. Satisfactory shale to mix with it may be obtained from nearby deposits in secs. 10 and 11, T. 33 N., R. 8 E. (Table 6), and possibly from shales underlying the limestone. Analyses of the clays in sections 10 and 11 follow.

Table 6.—*Analyses of clays in secs. 10 and 11, T. 33 N., R. 8 E.*

	1	2	3
Silica	53.48	62.32	63.48
Calcium oxide (lime)	1.32	1.39	.86
Calcium carbonate	2.36	2.48	1.54
Magnesium oxide (magnesia)	1.61	1.00	1.36
Magnesium carbonate	3.37	2.09	2.84
Ferric oxide (iron oxide)	7.26	1.96	2.61
Aluminum oxide (alumina)	24.53	25.36	23.30
Sulfur trioxide	3.11	1.00	1.14
Loss on ignition	8.11	7.14	7.02
Alkalies, by difference	.58	....	.23

1. Sample from 9-foot exposure of clay in Haeger Brick and Tile Company pit, NW. ¼ NE. ¼ sec. 10, T. 33 N., R. 8 E.

2. Sample from upper 4 feet of clay exposed in pit of Illinois Clay Products Company, near the center of sec. 11, T. 33 N., R. 8 E.

3. Sample from lower 8 feet of clay in pit of Illinois Clay Products Company, near the center of sec. 11, T. 33 N., R. 8 E.

Most of Illinois' cement is produced in the vicinity of LaSalle, about 45 miles west of the Divine area, where three companies are producing Portland cement. A fourth plant is located at Dixon. In 1929, Illinois plants sold 7,738,208 barrels of cement valued at $11,134,538 or $1.44 per barrel.

Agricultural Limestone

Agricultural limestone is pulverized or finely crushed limestone or dolomite. Its value from the standpoint of chemical composition is usually measured by its "calcium carbonate equivalent" which in the case of high-calcium limestones is approximately equal to the total amount of calcium and magnesium carbonate it contains. Commercial grades usually include stone consisting of not less than 90 per cent carbonates. The Divine limestone, with its carbonate content of almost 98 per cent, is an excellent agricultural limestone. The average price of agricultural limestone sold in Illinois in 1929 was 89 cents per ton (Table 5, p. 14). This figure includes the value of a large volume of screenings which are largely a by-product of limestone crushed for other purposes and sell for 50 to 70 cents per ton. Limestone especially pulverized for agricultural purposes usually brings a higher price than the Illinois average of 89 cents. For example, current quotations[7] indicate prices from $3.00 to $4.00 per ton for high-calcium limestones crushed so fine that 90 per cent of it passes a 100-mesh sieve.

[7] Rock Products Magazine, Feb. 28, 1931.

Limestone for Alkali Manufacture

Very pure limestones, low in silica, iron oxide, and alumina, are used in the manufacture of alkalies. The purity of the Divine stone makes it appear suitable for this purpose. No limestone for alkali works was produced in Illinois in 1929 but the average price in the United States was 67 cents per ton.

Limestone for Sugar Refining

Limestones containing more than 95 per cent calcium carbonate and less than one per cent each of silica, iron oxide, magnesia, alumina, sulfur dioxide, and other substances insoluble in hydrochloric acid are used in refining cane and beet sugar. The Divine limestone qualifies well for this use except that the iron oxide content is slightly more than one per cent, an excess so small that it would seem tolerable. No limestone for sugar refineries was produced in Illinois in 1929 but that produced in the United States sold for an average of $1.79 per ton (Table 5, p. 15).

Limestone for Paper Manufacture

High-calcium limestone is employed in the tower system of the sulfite process of paper manufacture. The Divine stone is doubtless suitable for this purpose. No limestone was produced for paper manufacture in Illinois during 1929. The average price per ton of limestone sold for paper manufacture in the United States in 1929 was $1.66 (Table 5).

Poultry Grit and Mineral Food

Finely crushed or pulverized limestone, high in calcium and low in magnesia, is used as poultry grit to furnish calcium carbonate for the formation of egg shells and bone, and similar stone in pulverized form is fed to stock, especially cows, to provide the calcium which is an important constituent of milk and bones. The Divine limestone would serve admirably for this purpose. Poultry grit is produced in Illinois but no figures are available as to its value. The average price for the grit produced in the United States is $6.40 per ton; mineral food averaged $3.80 per ton (Table 5).

Mineral Filler

Pulverized limestone is used as a mineral filler for various products, especially for asphalt. A considerable amount of white limestone is used for this purpose. Because it is stained buff or pink by a small amount of iron oxide, the Divine stone as observed in outcrops would not produce a pure white filler but would otherwise be satisfactory. The average price of limestone asphalt filler in 1929 was $3.37 per ton (Table 5).

Limestone for Rock Dusting in Coal Mines

Dusty coal mines are often sprinkled liberally with limestone dust in order to mix a non-inflammable material with the coal dust, thereby reducing the likelihood of coal-dust explosions. Limestone dust low in silica is used extensively for this purpose. The average price per ton in 1929 was $3.51 (Table 5, p. 15). The Divine limestone seems admirably suitable for this purpose.

Aluminum Refining

Limestone containing more than 97 per cent calcium carbonate and not more than 1 per cent silica is used in aluminum refining. The calcium carbonate content of the Divine limestone as tested is slightly below the requisite 97 per cent, but analysis of an unweathered sample may show that the stone meets the requirement. The silica content of the Divine stone is less than the permissible 1 per cent.

Stucco, Terrazzo, and Artificial Stone

Chips of crystalline limestone are often used for stucco and terrazzo and in making artificial stone. The Divine limestone will yield pinkish or brownish white chips, and by making selections when stripping the stone, brown and pink chips also can probably be produced from the weathered portions of the deposit. Limestone chips for stucco, terrazzo, and artificial stone sold at an average price of $3.42 in 1929 (Table 5).

Other Uses

The Divine limestone would probably be suitable for any other uses of stone requiring a material high in calcium carbonate and low in impurities.

The uses described below are those for which it is thought the Divine limestone may be satisfactory. However, additional data regarding the character and composition of the limestone are needed to determine its suitability for these purposes.

Building Stone

The Divine limestone is probably of value as building and decorative stone inasmuch as it takes a good polish and is available in several pleasing colors and textures. Three major varieties of stone were noted—cream toned, brown, and red. A well known cut-stone architect has described relatively small but typical polished specimens of these varieties as follows:

"Cream-toned stone; highly crystalline, takes a good polish that brings up the color of delicate pink, yellow, and other toned crystals which are attractively distributed and relieve the monotony of the stone.

"Brown stone; takes a good polish but not as good as cream stone. Polish brings out cream white of shell fragments and other fossil material giving contrast and accentuating the general brown color. Some of the fossils are large enough to stand out individually and show traces of their original shape.

"Red stone; red of flowered distribution on a background of cream buff giving a fleuri effect generally, but locally more concentrated with the darker color predominating. Takes a good polish."

The cream-toned stone is thought to be typical of the unweathered and unstained part of the Divine deposit. Blocks of this stone large enough to provide polished slabs for interior decoration can probably be obtained without great difficulty.

The brown and red varieties are characteristic of the surface iron-stained portion of the deposit and thick slabs of these varieties may be somewhat difficult to obtain. It seems probable, however, that blocks 6 and 12 inches thick may be secured in some places.

In general all three varieties appear to be suitable for most kinds of interior construction and decorative purposes. The cream-toned stone is probably satisfactory for exterior use but the brown and red stone should be thoroughly tested to determine their weather resistance before they are used for exterior construction.

Glass

If the content of iron oxide is not too high, the Divine limestone will probably meet the specifications for stone to be used in the manufacture of glass. A maximum of 0.1 to 0.3 per cent ferric oxide is permitted in limestone for glass making. The white or cream colored, unweathered Divine limestone may be satisfactory for this purpose but no data are available concerning the chemical composition of this part of the deposit. Limestone for glass factories sold for an average of $1.51 per ton in Michigan and $1.79 in United States in 1929 (Table 5, p. 15).

Whiting Substitute

Whiting substitute is finely pulverized, very white limestone. All the limestone that was seen in the Divine area deviated from a pure white color and therefore would not make a white whiting. Whiting made from the cream colored or slightly pinkish stone might, however, be acceptable for some uses. Whiting substitute sold for an average of $5.00 per ton in 1929 (Table 5).

Riprap and Rubble

The unweathered portions of the Divine deposit will probably yield stone suitable for riprap or rubble. Some of the pinkish-white coarsely crystalline stone should make an attractive rubble for certain types of masonry. The weathered surface stone is not recommended for riprap or rubble, however, because its weather resistance is thought to be relatively poor. Production statistics on riprap and rubble are given in Table 5.

Other Possible Uses

The Divine limestone may possibly be employed for the purposes mentioned below but probably less profitably than for uses described above.

Limestone used for concrete aggregate, ballast, road metal, and filters must have a high resistance to wear and to weather and must be produced at low cost (Table 5). The sample of exposed Divine limestone that was tested had a French coefficient of wear of 5 (Table 3). The unweathered stone may have a higher coefficient, possibly exceeding 6, which is the minimum commonly permissible for aggregate for concrete roads and for railroad ballast. Filter stone must endure conditions equivalent to severe weathering. Exploitation of the Divine limestone primarily for these uses is not recommended because the principal nearby markets for stone for these uses are already well supplied from high-grade, local sources and because the Divine stone is thought to be adapted for other purposes yielding a better price.

The Divine limestone has a moderately high cementing value (Table 3) so that it may bond well and from that viewpoint may be satisfactory for waterbound macadam roads, but owing to its softness it would probably develop a slight dustiness. Inasmuch as there is an ample supply of gravel in the Divine region it seems unlikely that the Divine limestone will be used extensively for constructing macadam roads.

State of Illinois
Department of Registration and Education
Division of the
STATE GEOLOGICAL SURVEY
M. M. Leighton, Chief

INFORMATION CIRCULAR NO. 4

Supplement to

Report of Investigations 23

RESULTS OF TEST-DRILLING OF LIMESTONE NEAR MORRIS, ILLINOIS

By J. E. Lamar and H. B. Willman

February, 1933

Illinois State Geological Survey
Urbana, Illinois

Information Circular No. 4 February, 1933

RESULTS OF TEST-DRILLING OF LIMESTONE NEAR MORRIS, ILLINOIS

By J. E. Lamar and H. B. Willman

SUMMARY

In 1931 the Illinois State Geological Survey published Report of Investigations No. 23, on "High-calcium limestone near Morris, Illinois," based on data obtained from surface outcrops and records of water wells.

The potential commercial importance of the deposit together with requests for further information and the acquisition of information not known to exist at the time of publication, emphasized the desirability of coring the deposit. Through the courtesy of the State Highway Division four borings with a diamond drill were made for the Geological Survey. Each boring passed through the limestone and entered shale.

The results of the borings and the chemical analyses of the cores are shown in Table 1. They indicate that in the tract south of Illinois River the upper few feet, to a maximum thickness of 4 or 5 feet, is usually high-calcium stone, most of it brown in color. This confirms the information obtained from outcrops. Below the high-calcium rock the amount of magnesium carbonate generally increases with depth. All samples of core tested had a high or moderately high total carbonate content.

BORING NO. 1

Boring No. 1 was located 60 feet east of the Elgin, Joliet and Eastern Railroad and 40 feet north of a small abandoned quarry about a quarter of a mile north of the grain elevator at Divine station, sec. 34, T. 34 N., R. 8 E.

Black soil 4 inches thick overlies the limestone. No core was obtained from the upper foot of the stone which was partly disintegrated but otherwise appeared to be similar to that immediately underlying. The two samples of core representing the next 3 feet 9 inches of stone contained respectively 98.1 and 97.0 per cent $CaCO_3$ and 1.7 and 2.7 per cent $MgCO_3$.

Illinois State Geological Survey
Urbana, Illinois

Information Circular No. 3 February, [illegible]

RESULTS OF TEST-DRILLING OF LIMESTONE NEAR MORRIS, ILLINOIS

By J. E. Lamar and H. B. Willman

SUMMARY

In 19[illegible] the Illinois State Geological Survey published Report of Investigations No. [illegible] [illegible]

The potential commercial importance of the [illegible] [illegible]

The results of the borings and the chemical analyses of the cores are shown in Table 1. [illegible]

BORING NO. 1

Boring No. 1 was located [illegible]

[illegible]

Below the high-calcium stone, the amount of $MgCO_3$ increases with depth, reaching a maximum of 34.9 per cent in the lower 10 1/2 feet of stone. The average composition of the entire core is 74.6 per cent $CaCO_3$ and 22.8 per cent $MgCO_3$. The total thickness of stone penetrated was 28 feet 11 inches.

BORING NO. 2

Boring No. 2 was located on the north side of the right-of-way of an east-west wagon road and 150 feet east of a lane leading north to a house near Dresden Island locks and dam, sec. 35, T. 34 N., R. 8 E.

The boring penetrated 6 inches of black soil overlying the bedrock limestone. Only 2 feet 3 inches of core was obtained in drilling through the upper 7 feet 11 inches of the deposit. Of this core, the upper 11 inches, representing a thickness of approximately 3 feet of the stone penetrated, was shown by analysis to fall short of the high-calcium limestone class by only 1/2 of 1 per cent. It contained 94.5 per cent of $CaCO_3$ and only 1.3 per cent magnesium carbonate. Below this, the magnesium carbonate content increases rapidly, reaching a maximum of 37.2 per cent in the lower 7 1/2 feet of stone. The average composition of the entire core is 69.5 per cent $CaCO_3$ and 26.3 per cent $MgCO_3$. The total thickness of stone penetrated is 26 feet 4 inches.

BORING NO. 3

Boring No. 3 was located about 150 feet south of an old corn-crib near the center of sec. 2, T. 33 N., R. 8 E.

The boring penetrated 2 feet 3 inches of soil overlying the limestone. The upper 1 foot 2 1/2 inches of core, representing approximately the upper 2 feet of the stone penetrated, is high-calcium stone containing 95.4 per cent of $CaCO_3$ and 2.5 per cent $MgCO_3$. The core representing the next lower 11 feet of stone contained 8 to 16 per cent $MgCO_3$, and the remainder of the core, representing the lower 13 feet, contained from 38 to 39 per cent $MgCO_3$. The average composition of the entire core was 71.6 per cent $CaCO_3$ and 25.0 per cent $MgCO_3$. A total of 26 feet 2 inches of stone was penetrated before blue shale was encountered.

BORING NO. 4

Boring No. 4 was located on the north side of the right-of-way of an east-west road and 90 feet west of the Elgin,

[illegible] the high-calcium stone. The amount of $MgCO_3$ [illegible] [illegible], reaching a maximum of 7.[illegible] per cent in the lower [illegible] feet of stone. The average composition of the [illegible] [illegible] is [illegible] per cent $CaCO_3$ and 22.[illegible] per cent $MgCO_3$. The [illegible] thickness of stone penetrated was [illegible] feet [illegible] inches.

BORING NO. 2

Boring No. 2 was located on the north side of the [illegible]-of-way of an east-west township road [illegible] 150 feet [illegible] of [illegible] [illegible] leading north to a point near Grand Island Lock and Dam, sec. 35, T. [illegible] N., R. 4 E.

The boring penetrated [illegible] inches of black soil over-lying the bedrock limestone. Only 2 feet 3 inches of core was obtained in drilling through the upper 7 feet 11 inches of the deposit. Of this core, the upper 11 inches, representing a thickness of approximately 1 1/2 feet of the stone penetrated, was dolomitic and [illegible] [illegible] part of the high-calcium limestone. [illegible] only 1/2 of 1 per cent. It contained [illegible].5 per cent of $CaCO_3$ and only 1.[illegible] per cent magnesium carbonate. Below this, the magnesium carbonate content increases rapidly, reaching a maximum of 37.[illegible] per cent in the lower 7 1/2 feet of stone. The average composition of the entire core is [illegible] per cent $CaCO_3$ and 21.3 per cent $MgCO_3$. The total thickness of stone penetrated is 2[illegible] feet [illegible] inches.

BORING NO. 3

Boring No. 3 was located about 150 feet south of an old north-south road [illegible] sec. [illegible], T. [illegible] N., R. [illegible] E.

The boring penetrated 2 feet 3 inches of soil over-lying the limestone. [illegible] 2 1/2 inches of core, [illegible] [illegible] [illegible] 2 feet of the stone [illegible] [illegible], is high-calcium limestone containing [illegible] per cent [illegible] [illegible] and [illegible] per cent $MgCO_3$. The [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of stone, [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the core, [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] per cent $MgCO_3$. The [illegible] composition of the [illegible] core is [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

BORING NO. 4

Boring No. 4 was located on the [illegible] [illegible] [illegible] [illegible]-of-way, [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

Joliet, and Eastern Railroad in sec. 22, T. 34 N., R. 8 E., on the north side of Illinois River.

At this location the strata penetrated were 13 inches of soil overlying 8 feet 4 inches of limestone below which blue shale was encountered. Analyses of the core indicate the entire thickness of stone to be magnesian. The upper 5 feet 1 inch contained 35.3 per cent $MgCO_3$ and the lower 3 feet 3 inches contained 15.7 per cent $MgCO_3$.

DISCUSSION

The stone encountered in boring No. 1, almost 29 feet thick, was somewhat thicker than anticipated on the basis of previous data. The rock in boring No. 2, 26 feet thick, was somewhat less than was expected on the basis of the reported 32 and 44 feet of stone encountered in water wells drilled respectively west and east of it. Boring No. 3 with 26 feet of stone gives information in an area where no data were previously available. The 8 feet of stone encountered in boring No. 4 on the north side of the river was much less than anticipated, as a well about a third of a mile northeast of the boring reported 36 feet of stone.

The fact that only the upper part of the deposit is high-calcium limestone restricts its use. The deposit would probably make satisfactory agricultural limestone. The stone below the high-calcium portion may be suitable for concrete aggregate, for road material, for certain types of mineral filler, for riprap, rubble, and building stone but further exploration of the deposit on a larger scale and testing of large samples would be necessary to determine its acceptibility for these uses.

The commercial feasibility of working the deposit so as to separate the upper high-calcium rock from the underlying magnesian beds is not known. The cores indicate that most of the high-calcium stone is buff or brown. It could probably be employed for those uses, as listed in Report of Investigations No. 23, which are not critical with regard to the color of the stone or its content of iron compounds.

The data afforded by the cores and their analyses indicate the variable nature of the deposit and confirm the recommendation made in the previous publication that it be thoroughly prospected before development is undertaken.

Joliet, and Eastern Railroad in sec. 22, T. 34 N., R. 9 E., on the north side of Illinois River.

At this location the strata penetrated were 17 inches of soil overlying 8 feet 4 inches of [illegible] below which blue shale was encountered. Analysis of the core indicate the entire thickness of stone to be dolomitic. The upper 5 feet 1 inch contained 37.3 per cent $MgCO_3$, and the lower 3 feet 3 inches contained 17.7 per cent $MgCO_3$.

DISCUSSION

The stone encountered in boring No. 1, about 45 feet thick, was somewhat thicker than anticipated [illegible] previous data. The rock in boring No. 2, 38 feet thick, was somewhat less than was expected on the basis of the [illegible] 37 and 41 feet of stone encountered in water wells [illegible] west and east of it. Boring No. 3 [illegible] gives information in an area where no data were previously available. The 8 feet of stone encountered in boring No. 4 on the north side of the river was much less than anticipated, as a well about a quarter of a mile northeast of the boring reported 36 feet of stone.

The fact that only the upper part of the deposit is high-calcium limestone restricts its use. The deposit would probably make satisfactory agricultural limestone. The stone below the high-calcium portion may be suitable for concrete aggregate, for road material, for certain types of mineral filler, for riprap, rubble, and building stone but further exploration of the deposit on a larger scale and tests of [illegible] quality would be necessary to determine its acceptability for these uses.

The commercial feasibility of working the deposit [illegible] the amount of high-calcium stone [illegible] [illegible]. The [illegible] [illegible] [illegible] of the high-calcium [illegible] or more. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] commonly.

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

TABLE 1 - DATA ON BORINGS IN THE DIVINE AREA

Depth below surface(1)	Character of limestone	Length of core	Thickness represented(1)		Carbonates(2) $CaCO_3$	$MgCO_3$	Total
Boring No. 1, NW. corner NE. 1/4 sec. 34, T. 34 N., R. 8 E.							
0'-0'4"	(Soil)	0'0"					
0'4"-1'4"	Brown, coarsely crystalline	0'0"					
1'4"-2'8"	Brown, coarsely crystalline	0'8"		1'4"	98.1	1.7	99.8
2'8"-5'1"	Brown, coarsely crystalline	1'0"		2'5"	97.0	2.7	99.7
5'1"-(10'4")	Brown and white, coarsely crystalline	2'5$\frac{1}{2}$"	(5'3")	7'10"	91.5	8.2	99.7
(10'4")-12'11"	Brown, white and gray	1'3$\frac{1}{2}$"	(2'7")		81.0	18.0	99.0
12'11"-18'9"	Gray and brown, porous in part	2'10"		5'10"	69.0	29.3	98.3
18'9"-(21'0")	Gray and brown, slightly porous	1'7$\frac{1}{4}$"	(2'3")	10'6"	62.0	34.9	96.9
(21'0")-29'3"	Gray, locally very porous; locally pyritic	4'11"	(8'3")		59.1	34.9	94.0
			Average(3)		74.6	22.8	97.4
Boring No. 2, Center S. line, SE.$\frac{1}{4}$ SW.$\frac{1}{4}$ NE.$\frac{1}{4}$ sec. 35, T. 34 N., R. 8 E.							
0'-0'6"	(Soil)	0'0"					
0'6"-(3'8")	Dark brown, ferruginous	0'11"	(3'2")	7'11"	94.5	1.3	95.8
(3'8")-8'5"	Dark brown, ferruginous	1'4"	(4'9")		83.5	14.0	97.5
8'5"-(11'8")	Light gray, locally brown	1'2"	(3'3")	6'6"	65.4	28.6	94.0
(11'8")-14'11"	Light gray	1'2$\frac{1}{2}$"	(3'3")		67.2	30.1	97.3

Depth below surface(1)	Character of limestone	Length of core	Thickness represented(1)		Carbonates(2) $CaCO_3$	$MgCO_3$	Total
		Boring No. 2 (continued)					
14'11"-19'4"	Light gray and gray, locally porous	3'11½"		4'5"	59.7	34.3	94.0
19'4"-26'10"	Light gray and gray, largely highly porous, locally pyritic	4'2"		7'6"	58.6	37.2	95.8
			Average(3)		69.5	26.3	95.8
<u>Boring No. 3, Center S. line, SW.¼ SW.¼ NE.¼ sec. 2, T. 33 N., R. 8 E.</u>							
0'-2'3"	(Soil)	0'0"					
2'3"-(4'5")	Brown, crystalline	1'2½"	(2'2")	5'1"	95.4	2.5	97.9
(4'5")-7'4"	Brown, crystalline, white at base	1'7½"	(2'11")		80.2	15.9	96.1
7'4"-(11'3")	Brown and light brown	1'4½"	(3'11")	8'1"	89.2	8.4	97.6
(11'3")-15'5"	Gray, white and brown	1'6¾"	(4'2")		80.6	16.5	97.1
15'5"-19'4"	Gray, upper part porous	1'9½"		3'11"	58.3	38.9	97.2
19'4"-23'6"	Gray and dark gray, locally porous	2'9"		4'2"	57.7	39.3	97.0
23'6"-26'2"	Gray and dark gray, locally porous	1'8"		2'8"	56.5	37.6	94.1
26'2"-28'5"	Gray and dark gray, with white mottlings	1'9"		2'3"	57.0	37.6	94.6
			Average(3)		71.6	25.0	96.6

Depth below surface(1)	Character of limestone	Length of core	Thickness represented(1)	Carbonates(2) $CaCO_3$	$MgCO_3$	Total
Boring No. 4, SW. corner, SE.¼ sec. 22, T. 34 N., R. 8 E.						
0'-1'1"	(Soil)	0'0"				
1'1"-6'2"	Brown and gray	0'9"	5'1"	58.8	35.3	94.1
6'2"-9'5"	Dark gray	0'7"	3'3"	77.9	15.7	93.6
			Average(3)	66.3	27.7	93.9
Railroad cut north of Divine, NW. cor. NE.¼ sec. 34, T. 34 N., R. 8 E.						
6"-4'0"	Coarsely crystalline, brown and pink		3'6"	97.6	2.1	99.7

(1) The length of the core obtained was usually less than the thickness of the rock penetrated due to the fact that some of the rock was ground up during drilling. In order to secure the maximum information regarding the chemical composition of the rock, it was necessary to divide some of the core at points whose exact depths were not known. In these cases it was assumed that the core was uniformly distributed throughout the interval which it represents and the resulting thicknesses are given in parentheses.

(2) Chemical analyses were made by the Analytical Division, State Geological Survey. In order to expedite preparation of this report a rapid method of analysis having an accuracy of ± 0.5 per cent on the basis of oxides, equivalent to approximately ±1.0 per cent on the basis of carbonates, was employed. Each analysis is the average of duplicate determinations calculated to the first decimal place. The accuracy of the analytical method is comparable to the probable accuracy of sampling.

(3) Average weighted according to thickness of rock.